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(54) **TEST APPARATUS AND CONTROL METHOD FOR TEST APPARATUS**

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Description

[0001] This application claims the priority to Chinese Patent Application No. 201610877233.9, titled "MAGNETIC POLE PART, FIBER-REINFORCED MATERIAL, TEST APPARATUS THEREFOR, AND CONTROL MEHTOD FOR TEST APPARATUS", filed on September 30, 2016 with the State Intellectual Property Office of People's Republic of China.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of adhesive filling and curing in a molding process for protecting a magnetic pole of a permanent magnetic machine, and in particular, to a magnetic pole member, a fiber-reinforced material, a test apparatus and a control method therefor.

BACKGROUND

[0003] JPH0694594A relates to an apparatus for evaluating surface characteristics of a resin. The resin to be evaluated is hung down from a load detector and liquid is poured in a liquid container. Water or an organic solvent is controlled at a specified temperature with a circulation temperature controller. By varying the liquid temperature continuously, dynamic contact angle of the resin can be measured.

[0004] The permanent magnetic machine is an electromagnetic apparatus which performs mutual conversion between mechanical energy and electric energy with magnetic field as a medium, and is widely applied to various scenes. Magnetism of the permanent magnetic material of the permanent magnetic machine is one of the most important factors which influence the power generation performance of the permanent magnetic machine.

[0005] Reference is made to Figure 1, which is a schematic diagram of a partial structure of a permanent magnetic pole of a permanent magnetic machine.

[0006] The permanent magnetic pole of the permanent magnetic machine includes a magnetic yoke wall 1, pressing bars 2 and a magnetic pole member 3. The magnetic yoke wall 1 is generally a cylindrical wall. The preprocessed pressing bars 2are installed at an inner peripheral wall of the magnetic yoke wall 1 through fasteners such as bolts 4 and the like. The pressing bars 2 extend along the axial direction, and are uniformly distributed along the circumferential direction. After positions of the pressing bars 2 are fixed, a magnetic pole member 3 is pushed along the axial direction into a corresponding position between adjacent pressing bars 2. The cross section of the pressing bars 2 is generally a trapezoid. Namely, two side walls of a pressing bar 2 are inclined surfaces of the trapezoid. The magnetic pole member 3 is confined along a radial direction inside a trapezoidal space formed between the adjacent pressing bars 2. The magnetic pole member 3 is a permanent magnetic material. The major component of the permanent magnetic material is neodymium iron boron. Iron and neodymium in the neodymium iron boron is apt to be oxidized, which causes a change in magnetic performance. Therefore, a protective coating 6 is generally poured at a surface of the magnetic pole member 3, so as to prevent an influence of an external environment on the magnetic properties of the magnetic pole member 3 as much as possible, and hereinafter a specific process is described in detail.

[0007] First, a vacuum bag is installed at an inner wall of the magnetic yoke wall 1. The vacuum bag and the magnetic yoke wall 1 form a mold cavity. The pressing bars 2 and the magnetic pole member 3 are wrapped in the mold cavity. Generally, a layer of fiber-reinforced material is laid in advance at the surface of the pressing bars 2, so as to increase strength of the protective coating 6. Afterwards, the mold cavity is pumped to vacuum by a vacuum pump, so that the reinforced material is tightly pressed against at the surface of the pressing bars 2 and the magnetic pole member 3, and residual air between the magnetic pole member 3 and the magnetic yoke wall 1 is extracted. Then, the adhesive (resin type) is poured in vacuum into the mold cavity. The resin, when flowing along the axial direction from one end to the other end of the mold cavity, impregnates the fiber-reinforced material, fills a gap between the magnetic pole member 3 and the magnetic yoke wall 1 and a gap between the magnetic pole member 3 and the pressing bars 2, and covers the surface of the pressing bars 2 and the magnetic pole member 3. After filling the whole mold cavity, spacing, and gaps, the adhesive wets and impregnates the contact surface to solid objects in the mold cavity, so as to control a curing process for forming the protective coating of the resin-based reinforced material.

[0008] The protective coating 6 has a good protection effect on the magnetic pole member 3 to some extent. In a long-term usage, moisture in ambient environment can cause a chemical change in the fiber and the adhesive matrix, resulting in a decline of a performance of the fiber and the matrix. Moisture can enter, via diffusion, the interface between the protective coating 6 and the pressing bar 2, and the interface between the protective coating 6 and the magnetic pole member 3, causing exfoliation of the mutually bonded interface and a decline of mechanical performance of the material. Under an environment where temperature and humidity change, mismatching deformation and mismatching stress are generated in the adhesive due to expansion and contraction, influencing structural deformation and causing damages to the material.

[0009] In a molding process, it is inevitable that there are many defects such as micro-cracks at the bonded interface.

Each micro-crack has a different state of stretching and shrinking in heating expansion and cooling contraction, resulting in inconsistency of the coefficient of thermal expansion during heating and cooling. The crack or the exfoliation area gradually increases, reducing a mechanical performance of the protective coating 6. In usage, water molecules are apt to first invade into free spaces and microscopic defects, such as holes, bubbles, and micro cracks, inside the protective coating 6, and hence moisture is absorbed fast at an early stage.

[0010] Therefore, how to improve a service life of the protective coating at the surface of the magnetic pole member of the machine is an urgent technical problem to be solved by those skilled in the art.

SUMMARY

[0011] To address the above technical issue, the invention is set out in the appended set of claims.

[0012] Thereby, when the test apparatus according to the present disclosure is used, the tested member such as a fiber-reinforced material or a magnetic pole member can first be placed at an appropriate position of the adhesive placing cavity via the positioning member. The adhesive placing cavity can hold a certain amount of adhesive. The adhesive temperature sensor can feed a real-time adhesive temperature back to the controller. The controller can control the adhesive heating member to be turned on or off, so that the adhesive is at the different temperatures. And the collecting member can acquire information of the meniscus at the different temperatures, calculate the corresponding contact angles, and finally display the adhesive temperature corresponding to the smallest contact angle.

[0013] The contact angles, at different adhesive temperatures, between the tested member and the adhesive can be acquired by the test apparatus. The test shows that contact angles between the same tested member and the adhesive are different at the different adhesive temperatures, and contact angles of different tested members are different at the same adhesive temperature. The adhesive temperature corresponding to a best contact angle of a certain tested member can be determined based on the test apparatus. Generally, the smaller the contact angle is, the better a wetting effect of a liquid on a solid is.

[0014] Namely, the best adhesive temperature of the fiber-reinforced material and the magnetic pole member, in a glue-injection process of a molding process for protecting the magnetic pole of a permanent magnetic machine, can be acquired in advance via the test apparatus according to the present disclosure, which facilitates acquiring data of critical factors which influence control of molding quality of the protective coating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Figure 1 is a schematic diagram of a partial structure of a permanent magnetic pole of a permanent magnetic machine;

Figure 2 is a schematic structural diagram of a test apparatus for member wettability research according to an embodiment of the present disclosure;

Figure 3 is curves of variations of a weight balancing member against time at different adhesive temperatures;

Figure 4 is a schematic structural diagram of a magnetic pole member;

Figure 5 is a schematic structural diagram of a test apparatus according to another embodiment of the present disclosure;

Figure 6 is an enlarged diagram of region A in Figure 5;

Figure 7 is a schematic diagram of flowing directions when mixing adhesive in a case that a top wall is a dome;

Figure 8 is a schematic diagram of a test apparatus; and

Figure 9 is a flowchart of a control method according to the present disclosure.

Reference signs in Figure 1:

[0016]

1:	magnetic yoke wall;	2:	pressing bar;
3:	magnetic pole member;	4:	bolt;
6:	protective coating.		

Reference signs in Figure 2 to Figure 8:

[0017]

10:	container;	101:	bottom wall;
102:	peripheral wall;	103:	top wall;

104:	outer shell;	104a:	inlet;
104b:	outlet;	105:	inner shell;
11:	adhesive temperature sensor;	12:	adhesive heating member;
121:	heating net;	121a:	wiring end;
122:	heating wire;	13:	fiber-reinforced material:
131:	transversal fiber;	132:	longitudinal fiber;
14:	suspension frame;	141:	lower positioning rib;
142:	middle positioning rib;	143:	upper positioning rib;
15:	heating wire;		
15a:	access end of an electric wiring end or a liquid pipe;		
16:	member temperature sensor;	161:	thermocouple wire;
162:	thermocouple temperature sensing section;		
17:	weight balancing member;	18:	bracket;
19:	lever;	20:	debonding layer;
21:	rotating shaft;	22:	controller;
23:	inner temperature sensor;	23a:	signal wire;
31:	stereo microscope;	32:	image collecting card;
33:	camera apparatus;	40:	magnetic pole member;
41:	magnetic body;	100:	adhesive.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0018] To address the technical problem that "there are defects such as micro-cracks in a practical molding forming process, resulting in a decline of the mechanical performance of the protective coating" mentioned in the background, various stages in forming the protective coating is thoroughly studied and explored according to the present disclosure.

[0019] The protective coating is mainly molded via a glue-injection process or a curing process. Devices mainly used in the glue-injection process include: a vacuum pump, a pressure regulating valve for the vacuum pump, a buffer tank (an adhesive collector), an adhesive storage tank, and a connecting hose. Under action of the vacuum pump, the adhesive in the adhesive storage tank is gradually injected via the hose into a vacuum bag. As described in the background, the adhesive (resin type) is poured in vacuum into a mold cavity, and the resin, when flowing along an axial direction from one end into the other end of the vacuum bag, impregnates a fiber-reinforced material, fills a gap between a magnetic pole member and a magnetic yoke wall and a gap between the magnetic pole member and pressing bars, and covers the surface of the pressing bars and the magnetic pole member. After filing the whole mold cavity, spacing, and gaps, the adhesive wets and impregnates the contact surface to solid objects in the mold cavity, so as to control the curing process for forming the protective coating of the resin-based reinforced material.

[0020] It is discovered according to the present disclosure that, besides the proportion of the adhesive, factors influencing the molding quality of the protective coating includes, for example, the adhesive temperature, and the temperature and material of members being in contact with the adhesive, such as the fiber-reinforced material and the magnetic pole member inside the vacuum bag, which all influence the molding of the protective coating.

[0021] With respect to how to set an appropriate adhesive temperature according to a specific fiber-reinforced material and magnetic pole member, so as to further improve the molding quality of the protective coating, thorough studies are carried out according to the present disclosure, and following technical solutions are proposed based on the studies.

[0022] For those skilled in the art to better understand the technical solutions according to the present disclosure, hereinafter the present disclosure is further illustrated in detail in conjunction with the drawings and specific embodiments.

[0023] Reference is made to Figure 2, which is a schematic structural diagram of a test apparatus for member wettability research according to an embodiment of the present disclosure.

[0024] A test apparatus for member wettability research is provided according to an embodiment of the present disclosure, which includes a container 10. A containing cavity with an enclosed structure is provided inside the container 10. The container 10 is provided with an adhesive placing cavity. The adhesive placing cavity is configured to hold a liquid adhesive 100. The adhesive placing cavity may be a part of the containing cavity in the container 10, or may be independent from the container 10, namely, the adhesive placing cavity being formed by an independent member placed in the containing cavity of the container 10. Generally, the container 10 includes a bottom wall 101, a peripheral wall 102, and a top wall 103, where the three walls enclose the containing cavity for holding the adhesive 100. The adhesive placing cavity is a partial space of the containing cavity.

[0025] The test apparatus further includes a positioning member for positioning a tested member at a corresponding position inside the container 10. During the test, a part of the tested member is located within the adhesive placing cavity to be in contact with the adhesive.

[0026] The test apparatus further includes an adhesive heating member 12, an adhesive temperature sensor 11, a collecting member, and a controller 22. The adhesive heating member 12 is arranged inside the adhesive placing cavity or outside the adhesive placing cavity, and configured to heat the adhesive 100. Namely, the adhesive heating member 12 may be arranged inside the adhesive placing cavity to directly heat the adhesive 100, or may be arranged outside the adhesive placing cavity to indirectly heat the adhesive 100. The adhesive temperature sensor 11 is configured to measure a temperature of the adhesive 100 inside the adhesive placing cavity. The adhesive temperature sensor 11 may be arranged at the bottom wall 101 of the adhesive placing cavity.

[0027] The collecting member is configured to acquire information of a meniscus formed between the tested member and the adhesive. The meniscus is formed at the contacting interface between the tested member and the adhesive, and is a curved surface along which part of the adhesive climbs from a liquid surface of the adhesive to a surface of the tested member.

[0028] A contact angle is an angle formed between a tangential direction at an upper edge of the meniscus and a vertical line.

[0029] The controller 22 is configured to control the operation of the adhesive heating member 12 to cause the adhesive to be at different temperatures, calculate, according to the information of the meniscus acquired at the different temperatures, corresponding contact angles between the tested member and the adhesive, and acquire an adhesive temperature corresponding to the smallest contact angle.

[0030] Thereby, when the test apparatus according to the present disclosure is used, the tested member such as a fiber-reinforced material 13 (such as a glass fiber-reinforced material) or a magnetic pole member 40 can first be placed at an appropriate position of the adhesive placing cavity via the positioning member. The adhesive placing cavity can hold a certain amount of adhesive 100.. The adhesive temperature sensor 11 can feed a real-time temperature of the adhesive 100 back to the controller 22. The controller 22 can further control the adhesive heating member to be turned on or off, so that the adhesive is at the different temperatures. And the collecting member can acquire the information of the meniscus at different temperature conditions, calculate the corresponding contact angles, and finally acquire the adhesive temperature corresponding to the smallest contact angle.

[0031] The contact angles, at different adhesive temperatures, between the tested member and the adhesive 100 can be acquired by the test apparatus. The test shows that contact angles between the same tested member and the adhesive 100 are different at different adhesive temperatures, and contact angles of different tested members are different at the same adhesive temperature. The adhesive temperature corresponding to a best contact angle of a certain tested member can be determined based on the test apparatus. Generally, the smaller the contact angle is, the better the wetting effect is.

[0032] Namely, the best adhesive temperature of the fiber-reinforced material 13 and the magnetic pole member 40, in a glue-injection process of a molding process for protecting the magnetic pole of a permanent magnetic machine, can be acquired in advance via the test apparatus according to the present disclosure, which facilitates acquiring a molding quality of the protective coating.

[0033] Based on the above research, it is further discovered according to the present disclosure that the contact angle between the adhesive 100 and the tested member can be further optimized by controlling in wetting a temperature of the fiber-reinforced material and a temperature of the magnetic pole member 40 to achieve a good match between temperatures of a covered material (or the tested member) and the adhesive 100. Hence, the test apparatus is further improved according to the present disclosure.

[0034] Further, the test apparatus may include a member heater and a member temperature sensor 16. The member heater is arranged inside the tested member, and configured to heat a covered surface of the tested member. Optionally, the member heater is a heating wire 15 buried in advance in the tested member. The heating wire 1 5 is configured to heat the tested member. It is taken as an example that the tested member is a glass fiber-reinforced material. The glass fiber-reinforced material includes a fiber body and the heating wire 15. The fiber body includes longitudinal fibers 132 and transverse fibers 131. The longitudinal fibers 132, the transversal fibers 131, and the heating wire 15 are woven together to form the glass fiber-reinforced material. The heating wire 15 may be uniformly wrapped inside the glass fiber-reinforced material. An accessing end 15a of an electrical wiring end sticks out from an upper part of the glass fiber-reinforced material, so as to facilitate connection with an external circuit.

[0035] The heating wire 15 is wrapped inside the fibers. Namely, multiple fibers wraps the hating wired 15, so that the heating wire is not exposed, is not in direct contact with the adhesive, and does not change a surface property of the reinforced material, such as roughness and density at the surface. Thereby, the heating wire does not influence the contact condition between the whole fiber-reinforced material and the adhesive.

[0036] Reference is made to Figure 4, which is a schematic structural diagram of a magnetic pole member 40.

[0037] Similarly, in a case that the tested member is the magnetic pole member 40, the member heater may be buried inside a magnetic pole material when the magnetic pole member 40 is prefabricated. Specifically, the magnetic pole member may include a magnetic body 41. The magnetic body 41 is mainly made of metallurgical powder, and has the same composition as conventional magnetic steel, which is not further introduced herein. The magnetic pole member 40 according to the present disclosure may further include the aforementioned member heater and the aforementioned member temperature sensor. The member heater is arranged inside the magnetic body 41 to heat the magnetic body 41.

[0038] The member heater may be a heating wire, a heating rod or a heating tube. The member heater is buried inside the magnetic body 41 when the magnetic body 41 is prefabricated, namely, when the metallurgical powder is pressed.

[0039] It is understood that, in order to heat the outer surface of the magnetic body 14 as uniformly as possible, the heating wire or the heating tube may be uniformly formed inside the magnetic body 41 and arranged close to the surface of the magnetic body 41, facilitating heating the magnetic body 41 rapidly. The access end 15a of the electrical wiring end or the liquid tube extends from inside to outside of the magnetic body 41 to be connected to an external heating source.

[0040] The member heater forms a continuous electric heating element inside the magnetic body 41, which facilitates a uniform distribution of the generated heat. Or the member heater is a net structure, formed by an electric heating element, inside the magnetic body 41. The net structure starts fast to generate heat, and facilitates a uniform distribution of the generated heat. The net structure may constitute multiple paths of parallel connection.

[0041] The member heater may be arranged inside the magnetic body 41 in various manners, which are not numerated herein.

[0042] The outer surface of the member heater may be covered by an insulation material, so as to prevent conduction between the member heater and the magnetic body 41.

[0043] Further, the magnetic body 14 may be provided with a humidity sensor inside. A humidity sensing member of the humidity sensor is formed at the surface of the magnetic body 41, and a wire of the humidity sensing member of the humidity sensor is formed inside the magnetic body 41. Inside formation of the wire does not change the surface condition of the magnetic body.

[0044] Similarly, the member temperature sensor 16 is configured to measure a surface temperature of the tested member. The member temperature sensor 16 may be arranged at the surface of the tested member, and also may be buried inside the tested member.

[0045] Similarly, the fiber-reinforced material and the magnetic pole member 40 are taken as an example, where the member temperature sensor is configured to measure a surface temperature of the fiber body or the magnetic body 41. Specifically, the temperature sensor includes a temperature sensing part and a conducting part. The temperature sensing part is configured to measure a temperature, and at least part of the temperature sensing part abuts against an outer surface of the fiber body or the magnetic body 41. The conducting part is buried inside the magnetic body 41, one end of the conducting part is connected to the temperature sensing part, and another end of the conducting part is exposed to the outside of the magnetic body 41.

[0046] The controller 22 further controls the operation of the member heater so that the tested member is at different temperatures, acquires information of the meniscus for different temperature gradients of a bonding layer between the tested member and the adhesive, calculates corresponding contact angles according to the information of the meniscus, and acquire a temperature of the tested member and an adhesive temperature, corresponding to the smallest contact angle.

[0047] Specifically, an end portion of the aforementioned conducting part of the temperature sensor, which is connected to outside, may stick out from inside of the tested member to be connect to the controller 22. Specifically, the member temperature sensor 16 may be a thermocouple sensor, including a thermocouple wire 161 and a thermocouple temperature sensing section 162. The thermocouple temperature sensing section 162 measures a surface temperature of the tested member located in the adhesive.

[0048] In the embodiment, the member temperature sensor 16 can transfer the surface temperature of the tested member to the controller 22, and the controller 22 may control the member heater buried in the tested member to heat the tested member. Test shows that the same tested member at the same adhesive temperature has different contact angles at different surface temperatures of the tested member. Taking an example that the tested member is a glass fiber-reinforced material, the following table shows the contact angles between the glass fiber-reinforced material and the adhesive 100 at the same adhesive temperature and different covered-surface temperatures.

Table 1 Contact angles at different temperatures of the glass fiber-reinforced material and the adhesive

Surface temperature of the glass fiber-reinforced material (°C)	20	30	40	50
Adhesive temperature (°C)	30	30	30	30
Contact angle (°)	56	52	40	34

[0049] Further, the test apparatus in the aforementioned embodiments may include an inner temperature sensor 23, which is arranged inside the tested member and configured to measure an inner temperature of the tested member. A signal output end of a signal wire 23a of the inner temperature sensor 23 may be connected to a signal input end of the controller, and the controller display on a display screen a temperature detected by the inner temperature sensor. Thereby, it is facilitated that a tester further learns, according to the temperature detected by the inner temperature sensor, about a heating power of the member heater and a relationship between the heating power of the member heater and the surface temperature of the tested member, and acquires a thermal diffusion rate from inside to the outer surface of the tested member and a degree of an influence from the temperature of the adhesive outside.

[0050] Further, the positioning member according to the present disclosure may include a lever 19. The lever 19 can rotate around a fixed fulcrum. The tested member located within the adhesive placing cavity is suspended at one end of the lever 19, and a weight balancing member 17 is arranged at another end of the lever 19. The weight balancing member 17 is configured to balance a force on the tested member so that the lever 19 is at a balanced position.

[0051] Optionally, the lever according to the present disclosure is an equal arm lever 19, so as to facilitate following calculations. It should be noted that forced on the tested member within the adhesive placing cavity include gravity and a buoyancy force from the adhesive 100, and the buoyancy force points upward. With respect to the equal arm lever 19, the weight of the weight balancing member 17 is a vector sum of the buoyance force and a wetting force on the tested member, in a case that the lever 19 is balanced. The weight balancing member 17 may be a weight block marked with a specific value.

[0052] For a tested member with a small weight, a suspension frame is generally further arranged. The fiber-reinforced material is positioned flatly on the suspension frame. An upper end of the suspension frame 14 is connected to the lever 19. Specifically, the suspension frame at least includes an upper positioning rib 143, a lower positioning rib 141 and a middle positioning rib 142, where the fiber-reinforced material is positioned flatly via the positioning ribs. During test, a surface contact section between the fiber-reinforced material 13 and the adhesive 100 is located between the lower positioning rib 141 and the middle positioning rib 142. Namely, the lower position rib 141is generally located at an end of the fiber-reinforced material 13 and submerged within the adhesive 100.

[0053] Reference is made to Figure 3, which are curves of variations of the weight balancing member against time at different adhesive temperatures.

[0054] Experiments show that, in a gradual wetting process of the tested member, the lever 19 is not always balanced, and variations of the weight balancing member 17 are shown in Figure 3 to keep a balance of the lever 19. In Figure 3, a curve S1 is a variation curve corresponding to adhesive temperature T_B, a curve S2 is a variation curve corresponding to adhesive temperature T_A, and T_A is greater that T_B. The weight of the weight balancing member 17 first decreases, and then gradually increases until reaching a fixed value. Namely, the viscosity of the adhesive 100 in the adhesive placing cavity is changing. Taking the curve S1 as an example, the viscosity decreases during the period from 0 to τ_0. At the moment when the viscosity of the adhesive decreases to the smallest value, it reaches a best state for flowing under which it is best for wetting and impregnation to reinforce the gap of the material and the surface of the magnetic member; and the viscosity increases during the period fromτ_0 to τ_1. From this figure, it can be seen that after the mass of the weight balancing member reaches m_0 again, the changing rate per unit of the weight of the weight balancing member is accelerated, namely, the viscosity of the adhesive increases rapidly.

[0055] Moreover, it can be seen from the curves drawn by the above test that τ_2 is greater than τ_1, namely, the curve S2 shows that a moment when the viscosity of the adhesive decreases to a minimum value is later than that of S1. That is to say, the higher the adhesive temperature is, the later the moment when the viscosity decreases to the minimum value is.

[0056] The above test shows that at a certain adhesive temperature, adhesive injection, gap filling, impregnation of the glass fiber cloth, and wettability of the permanent magnetic pole member 40 are completed within a permitted time interval, during which the viscosity increases and fluidity decreases, and thereby a reasonable glue -injection time is acquired.

[0057] In the above embodiments, the test apparatus may further include a bracket 18 supported on the ground or the test stand. The fixed fulcrum of the lever 19 is formed at the top of the bracket 18. Namely, the lever 19 is supported on the top of the bracket 18, and can rotate around the top of the bracket 18.

[0058] The lever 19 and the bracket 18 are arranged outside the adhesive placing cavity, and are convenient to install. The lever 19 may be connected via a pull cord or a pull rod to the tested member. Namely, a lower end of the pull cord or the pull rod is connected to an upper portion of the tested member, and an upper end of the pull cord or the pull rod goes through a via hole at the top wall of the adhesive placing cavity, and is connected to a corresponding end of the lever 19.

[0059] The test apparatus according to the aforementioned embodiments may further include a power member. The power member is configured to drive the container 10 to rotate around its vertical central axis. Specifically, the bottom wall 101 of the container 10 may be fixed on a platform, and the power member drives the platform to rotate, thereby achieving rotation of the container 10. The power member may be a motor. Because a volume of the test apparatus is not large, power of the motor may be small and can be driven by a battery. It is appreciated that the power member may be members such as a hydraulic pump and a motor, and a specific structural form of the power member is not limited according to the present disclosure, as long as rotation of the container 10 can be achieved. Although Figure 2 shows only a rotating shaft 21 connected to the power member and does not show the power member, those skilled in the art can still appreciate the technical solution according to the present disclosure.

[0060] Thereby, in the initial stage, the power member can drive the container 10 to rotate, and the adhesive 100 and the curing agent within the container 10 can be uniformly mixed. Then, the tested member is positioned at an appropriate position in the adhesive placing cavity for a wettability test.

[0061] Reference is made to Figure 2 again in conjunction with Figure 7, where Figure 7 is a schematic diagram of flow directions of the adhesive 100 when it is mixed in a case that the top wall is a dome.

[0062] An inner surface of the top wall of the container 10 is dome-shaped. When the mixture of the adhesive 100 climbs to a predetermined position of the dome-shaped inner wall, it will fall down to the inside of the adhesive placing cavity under gravity. Namely, the flowing form of the adhesive 100 has circumferential rotation superposed with upward and downward reciprocating rolling, which facilitates rapid mixing of the adhesive and the curing agent.

[0063] In an optional embodiment, the adhesive heating member 12 is a heating net uniformly distributed inside the adhesive placing cavity, so as to facilitate heating the adhesive 100 rapidly and uniformly.

[0064] It should be appreciated that the adhesive heating member 12 may also be a heating wire 122 arranged inside an inner wall of the container 10. A wiring end of the heating wire 122 and a wiring end 121a of the heating net 121 are exposed to the outside of the container 10.

[0065] The heating net 121 arranged inside the adhesive placing cavity or the heating wire 122 arranged in the inner wall of the container 10 may be arranged alternatively or both, thereby complementing each other.

[0066] In the aforementioned embodiments, the information of the meniscus acquired by the collecting member of the test apparatus may be an image or a video of the meniscus. The signal output port of the collecting member is connected to the signal input end of the controller 22, so as to transmit the image or the video of the meniscus to the controller 22. The controller 22 performs image processing or video processing on the image or the video of the meniscus, to acquire the contact angle between the adhesive and the tested member.

[0067] In the embodiment, the collecting member can acquire the contact angle accurately and rapidly, improving efficiency of the test and analysis accuracy of a test result.

[0068] Reference is made to Figure 5, which is a schematic structural diagram according to another embodiment of the present disclosure. Figure 6 is an enlarged diagram of section A in Figure 5.

[0069] In a specific embodiment, the collecting member includes a camera apparatus 33, a microscope 31 and an image collecting card 32. The camera apparatus 33 is configured to acquire the image of the meniscus. The microscope 31 is configured to enlarge the image of the meniscus which is acquired by the camera apparatus 33, and may be a stereo microscope. The image collecting card 32 receives the image of the meniscus which is enlarged by the microscope 31, and displays clearly on a display screen the image of the meniscus with a sampling rate determined by the controller 22.

[0070] The image collecting card 32 may be a high-speed image collecting card. The camera apparatus may be a CCD camera. The microscope 31 may be a stereo microscope. The CCD camera of the high-speed CCD image collecting system is connected to the stereo microscope 31 and docked with a thermal insulating cavity, to observe and record a test process inside the cavity. The image collecting card 32 transmits the microscopically enlarged image or video of the meniscus between the adhesive 100 (resin) and air to the controller 22. Self-programed software is configured in the controller 22 for real-time display and collection. An enlargement factor of the image may be adjusted based on test requirements. The dynamic contact angle is acquired by directly measuring an angle of the meniscus.

[0071] Figure 6 shows a static contact angle θ_a, a dynamic contact angle θ_b, and liquid surface tensions σ_a and σ_b, of the magnetic pole member 40 at temperatures T_A and T_B. The static contact angle is an angle between a tangential line of the meniscus and a vertical direction when the solid-state tested member stands in the liquid vertically, and the meniscus appears at two sides of the solid-state tested member due to capillary action. In a case that a thin plate is inserted downwards into (or in an opposite direction) a liquid sink at a constant speed v, the meniscus lowers and eventually keeps a stable shape, and the corresponding contact angle is the dynamic contact angle. The dynamic contact angle is greater that the static contact angle, and increases with the speed v of the thin plate increasing. Generally, a width of a side face (a left side face and a right side face) of the magnetic pole member 40 is 10 times or more of a width of a front face (or a back face), and an influence of the boundary of the front face (or the back face) of the magnetic pole member 40 on the meniscus of the side face (the left side face and the right side face) of the magnetic pole member 40 can be neglected.

[0072] According to the present disclosure, the left side face and the right side face of the magnetic pole member are defined with respect to the member position in Figure 4, and the left side face and the right side face are two faces having largest surface area.

[0073] Part of the magnetic pole member 40 is immersed into the adhesive 100 (resin and curing agent). Another end of the magnetic pole member 40 is suspended on the lever 19. The maximum pulling force required for the magnetic pole member 40 to be out of the liquid surface is measured. The maximum pulling force equals the weight of the magnetic pole member 40 in the air plus the wetting force $L\sigma\cos\theta$ generated by the adhesive 100 at the surface of the magnetic pole member 40, where σ is a surface tension of the liquid.

[0074] In a case that the magnetic pole member 40 is in an equilibrium state in Figure 5, $F\text{-}Mg=L\sigma\cos\theta - F_b$.

[0075] F is the balance pull, with a unit of newton (symbol N).

[0076] Mg is the gravity of the magnetic pole member 40, with a unit of newton (symbol N).

[0077] F_b is a buoyancy force, with a unit of newton (symbol N).

[0078] $L\sigma\cos\theta$ is the wetting force, with a unit of newton (symbol N).

[0079] $F_b = \rho gSh$, with a unit of newton (symbol N).

[0080] L is a wetted perimeter of a to-be-tested solid, with a unit of meter (symbol m).

[0081] θ is the contact angle, with a unit of degree.

[0082] σ is the surface tension of the liquid, with a unit of newton per meter (symbol N/m).

[0083] ρ is a density of the liquid, with a unit of kilogram per cubic meter (symbol kg/m^3).

[0084] S is a bottom area of the solid, with a unit of square meter (symbol m^2).

[0085] H is a depth at which the solid is immersed into the liquid, with a unit of meter (symbol m).

[0086] Thereby, the contact angle is calculated by a method of measuring a force. When the three-phase contact line moves forward (by uniformly adding weights with a small mass) and backward (by uniformly removing weights with a small mass) at a constant rate, the dynamic contact angle is measured as $\theta = \arccos[(F+F_b)/(L\cdot\sigma)]$. The mass of the weight may be fabricated to be small, so as to be added or removed uniformly.

[0087] In order to reduce loss of energy in the aforementioned test as much as possible, the container 10 of the aforementioned test apparatus includes an outer shell 104 and an inner shell 105. The adhesive placing cavity is formed inside the inner shell 105. The heat insulating cavity is formed between the outer shell 104 and the inner shell 105. A heat insulating material is contained in the heat insulating cavity.

[0088] Or, the outer shell 104 is provided with an inlet 104a and an outlet 104b, which are in communication with the heat insulating cavity. The inlet 104a and the outlet 104b may be connected to an external heat insulating medium loop. The heat insulating medium in the external heat insulating medium loop may be gas or liquid.

[0089] The heat insulating material or the heat insulating medium facilitates isolation between the inner shell and an external environment. The heat insulating material and the heat insulating medium are capable to effectively block thermal transmission between inside of the inner shell and the external environment. In particular, the container 10 can greatly improve efficiency of a test, in a case that the test apparatus is applied in an environment with a low temperature.

[0090] In addition, the adhesive placing cavity of the container 10 may further include a gas cavity. The gas cavity is located around the adhesive placing cavity or above the adhesive placing cavity. The gas cavity is configured to be filled with the gas which meets the test condition. Thereby, the gas cavity is filled with humid gas or dry gas, so as to simulate a practical processing environment. In particular, the test apparatus can simulate an influence of humidity of the install environment on the adhesive 100, under a practical processing condition that the magnetic pole member 40 enters an install process from a dry preserving environment, so as to verify an influence of a humid environment on an adhesive adhesion force and the contact angle.

[0091] In order to facilitate a tester to directly observe the wetting condition of the adhesive 100 and the tested member in the container 10, the container 10 may be entirely or partially made of a transparent material.

[0092] It should be appreciated that, in order to reduce a friction between the mixture of the adhesive 100 and the inner wall of the adhesive placing cavity, a debonding layer 20 formed by a debonding material may be arranged at the inner wall of the adhesive placing cavity.

[0093] The test apparatus according to the present disclosure can adjust a surface energy of the tested material by heating the tested member (such as the glass fiber-reinforced material and the magnetic pole member 40), adjust the temperature, the viscosity and the surface energy of a liquid such as the adhesive in contact with the tested member, and search for a temperature at which the adhesive 100 wets the tested member well. Namely, the test apparatus according to the present disclosure is capable to actively control a temperature difference of a solid-liquid contact interface when the magnetic pole member 40 and the glass fiber-reinforced material are individually or collectively in contact with the adhesive.

[0094] Generally, the adhesive which adheres to the tested member is the adhesive located within a predetermined distance from the covered surface. In the technical field, the adhesive within the predetermined distance range is defined as a bonding layer c.

[0095] Comprehensive reference is made to Figure 8, which is a schematic diagram of a test apparatus.

[0096] In the aforementioned embodiments, the adhesive temperature sensor 11 may be arranged at a boundary of the bonding layer c formed by the adhesive and the tested member, so as to accurately determine a temperature gradient formed by the tested member and the adhesive.

[0097] It should be noted that the temperature gradient is a ratio of a temperature difference between the surface of the tested member and the adhesive to a thickness of the bonding layer. The thickness of the bonding layer is on the order of millimeter, such as within 2mm.

[0098] Reference is made to Figure 9, which is a flowchart of a control method according to the present disclosure.

[0099] Based on the aforementioned test apparatus, a control method is provided according to the present disclosure, and the control method specifically includes the following steps.

[0100] In step S1, the adhesive temperature and the surface temperature of the tested member are controlled, so as to control the temperature gradients of the bonding layer between the adhesive and the tested member.

[0101] In step S2, multiple groups of contact angles formed between the adhesive and the tested member at the different temperature gradients are acquired, and the temperature of the tested member and the adhesive temperature corresponding to the smallest contact angle serve as control parameters for forming a protective coating.

[0102] Generally, the temperature of the contact interface of the tested member and the adhesive temperature corresponding to the smallest static contact angle are selected to serve as a temperature of the glue injected into the vacuum bag and a surface temperature of the glass fiber-reinforced material or the magnetic pole member 40 in a practical glue-injection operating condition.

[0103] As described above, the contact angles at the different temperature gradients may be obtained by acquiring the information of the meniscus formed between the tested member and the adhesive and calculating the contact angle according to the information of the meniscus.

[0104] The result of tests and research herein is instructive to molding technique of the protective coating of the magnetic pole of the permanent magnetic machine. Namely, the aforementioned test method is used to find a best mutual temperature, a novel measuring method thereof, and a dry degree (or a relative humidity), for wettability of the adhesive 100 on the fiber-reinforced material 13 and the magnetic pole member 40 (magnetic steel), and create an adjustable surface state of an objective material necessary for the test conditions.

[0105] The beneficial effect of the test apparatus is introduced hereinabove by taking the example that the tested member is the magnetic pole member 40 and the fiber-reinforced material 13. It should be appreciated that the test apparatus may apply to other tested members according to the present disclosure.

[0106] Hereinabove the magnetic pole member, the fiber-reinforced material, the test apparatus and the control method therefor are introduced in detail according to the present disclosure. Specific embodiments are applied in the present disclosure to illustrate the principle and embodiments of the present disclosure, and illustration of the above embodiments is to help understand the method and the key concepts of the present disclosure. It should be noted that those skilled in the art may make various improvements and modifications to the present disclosure without deviating from the principle of the present disclosure, and the improvements and the modifications fall within the protection scope claimed by the present disclosure.

Claims

1. A test apparatus for member wettability research, comprising:

   a container (10), wherein an adhesive placing cavity configured to hold an adhesive (100) is provided inside the container (10);
   a positioning member, configured to position a tested member at the adhesive placing cavity of the container (10), so that a part of the tested member is placed in the adhesive;
   an adhesive heating member (12), arranged inside or outside the adhesive placing cavity and configured to heat the adhesive (100);
   an adhesive temperature sensor (11), configured to measure a temperature of the adhesive inside the adhesive placing cavity;
   a collecting member, configured to acquire information of a meniscus formed between the tested member and

the adhesive (100); and
a controller (22), configured to control operation of the adhesive heating member (12) to cause the adhesive (100) to be at different temperatures, calculate, according to the acquired information of the meniscus at the different temperatures, corresponding contact angles between the tested member and the adhesive (100), and acquire a temperature of the adhesive (100) corresponding to a smallest contact angle,
characterized by further comprising a member heater and a member temperature sensor (16), wherein:

the member heater is arranged inside the tested member and configured to heat a covered surface of the tested member;
the member temperature sensor (16) is configured to measure a surface temperature of the tested member in contact with the adhesive; and
the controller (22) is further configured to control operation of the member heater to cause the tested member to be at different temperatures, acquires the information of the meniscus for different temperature gradients of a bonding layer between the tested member and the adhesive, calculates corresponding contact angles according to the information of the meniscus, and acquires a temperature of the tested member and the temperature of the adhesive corresponding to the smallest contact angle.

2. The test apparatus according to claim 1, wherein the member heater is buried in advance inside the tested member; the member temperature sensor (16) comprises a temperature sensing part and a conducting part; the temperature sensing part is configured to measure a temperature, and at least a part of the temperature sensing part abuts against the covered surface of the tested member; and the conducting part is buried inside the tested member, one end of the conducting part is connected to the temperature sensing part, and another end of the conducting part extends out of the inside of the tested member to be connected to the controller (22).

3. The test apparatus according to claim 2, further comprising an inner temperature sensor, which is arranged inside the tested member and configured to detect an inner temperature of the tested member.

4. The test apparatus according to any one of claims 1 to 3, wherein the positioning member comprises:

a lever (19), capable to rotate around a fixed fulcrum, wherein the tested member located within the adhesive placing cavity is suspended at one end of the lever (19), a weight balancing member (17) is arranged at another end of the lever (19), and the weight balancing member (17) is configured to balance a force on the tested member so that the lever (19) is at a balanced position,
wherein the test apparatus further comprises a bracket (18) supported on ground or a test stand, wherein the fixed fulcrum of the lever (19) is formed at a top of the bracket (18).

5. The test apparatus according to claim 4, wherein the container (10) comprises a bottom wall (101), a peripheral wall (102) and a top wall (103), the bottom wall (101), the peripheral wall (102) and the top wall (103) encloses a containing cavity, and the adhesive placing cavity is a part of the containing cavity; and the test apparatus further comprises a pull cord or a pull rod, a lower end of the pull cord or the pull rod is connected to an upper portion of the tested member, and an upper end of the pull cord or the pull rod goes through a via hole at the top wall and is connected to a corresponding end of the lever (19), and
wherein the containing cavity of the container (10) further comprises a gas cavity, the gas cavity is located around the adhesive placing cavity or above the adhesive placing cavity, and the gas cavity is configured to be filled with a gas which meets a test condition.

6. The test apparatus according to claim 1, further comprising a power member, wherein the power member is configured to drive the container (10) to rotate around a vertical central axis thereof, wherein:

the adhesive heating member (12) is a heating net (121) uniformly distributed within the adhesive placing cavity; and/or
the adhesive heating member (12) is arranged inside an inner wall of the container (10), and an wiring end of the adhesive heating member (12) is exposed to an outside of the container (10).

7. The test apparatus according to any one of claims 1-3 and 6, wherein the information of the meniscus acquired by the collecting member is an image or a video of the meniscus, a signal output port of the collecting member is connected to a signal input end of the controller (22) and transmits the image or the video of the meniscus to the controller (22), and the controller (22) performs image processing or video processing on the image or the video of the meniscus to acquire the contact angles between the adhesive and the tested member.

8. The test apparatus according to claim 7, wherein the collecting member comprises a camera apparatus (33), a microscope (31) and an image collecting card (32);
the camera apparatus (33) is configured to acquire the image of the meniscus; the microscope (31) is configured to enlarge the image of the meniscus which is acquired by the camera apparatus (33); and the image collecting card (32) receives the image of the meniscus which is enlarged by the microscope (31), and displays on a display screen the image of the meniscus with a sampling rate determined by the controller (22).

9. The test apparatus according to claim 4, wherein the member heater is a heating wire (15), the tested member is a fiber-reinforced material (13) which is woven by the heating wire (15) and a plurality of fibers, and the heating wire (15) is wrapped inside the fibers; and the test apparatus further comprises a suspension frame (14), the fiber-reinforced material (13) is positioned flatly on the suspension frame (14), and an upper end of the suspension frame (14) is connected to the lever (19).

10. The test apparatus according to claim 7, wherein the container (10) comprises an outer shell (104) and an inner shell (105), the adhesive placing cavity is formed inside the inner shell (105), a heat insulating cavity is formed between the inner shell (104) and the outer shell (105), and a heat insulating material is contained in the heat insulating cavity; or
the outer shell (104) is provided with an inlet (104a) and an outlet (104b), which are in communication with the heat insulating cavity, and the inlet (104a) and the outlet (104b) are connected to an external heat insulating medium loop.

11. The test apparatus according to any one of claims 1-3 and 6, wherein the adhesive temperature sensor (11) is arranged at a boundary of a bonding layer formed by the adhesive and the tested member.

12. The test apparatus according to claim 1, wherein the tested member is a magnetic pole member (40) or a fiber-reinforced material,
wherein the magnetic pole member (40) comprises:

> a magnetic body (41);
> wherein the member heater is arranged inside the magnetic body (41) and configured to heat the magnetic body (41); and
> the member temperature sensor is configured to measure a surface temperature of the magnetic body (41), and wherein the fiber-reinforced material comprises:
>
> > a fiber body;
> > wherein the member heater is arranged inside the fiber body and configured to heat the fiber body; and
> > the member temperature sensor is configured to measure a surface temperature of the fiber body.

13. The test apparatus according to claim 12, wherein the member heater is uniformly formed inside the magnetic body (41), and is arranged close to a surface of the magnetic body (41),

> wherein an outer surface of the member heater is wrapped by an insulation material,
> wherein the member heater is a heating wire, a heating rod, or a liquid heating pipe, or the member heater forms a continuous electric heating element inside the magnetic body (41), or the member heater is a net structure formed inside the magnetic body (41) by an electric heating element,
> wherein the member temperature sensor comprises a temperature sensing part and a conducting part; the temperature sensing part is configured to measure a temperature, and at least a part of the temperature sensing part abuts against an outer surface of the magnetic body (41); and the conducting part is buried inside the magnetic body (41), one end of the conducting part is connected to the temperature sensing part, and another end of the conducting part is exposed to an outside of the magnetic body (41), and
> wherein the test apparatus further comprises an inner temperature sensor, arranged inside the magnetic body (41) and configured to detect an inner temperature of the magnetic body (41).

14. The test apparatus according to claim 12, wherein the member heater is uniformly wrapped inside the fiber-reinforced material, and arranged close to a surface of the fiber-reinforced material,

> wherein the member heater is a heating wire (15), the fiber body comprises a plurality of fibers, the heating wire

(15) and the fibers are woven together to form the fiber-reinforced material, and the heating wire (15) is wrapped by the fibers, and

wherein the member temperature sensor comprises a temperature sensing part and a conducting part; the temperature sensing part is configured to measure a temperature, and at least a part of the temperature sensing part abuts against an outer surface of the fiber-reinforced material; the conducting part is buried inside the fiber body, one end of the conducting part is connected to the temperature sensing part, and another end of the conducting part is exposed to an outside of the fiber body, and

wherein the test apparatus further comprises an inner temperature sensor, arranged inside the fiber body and configured to detect an inner temperature of the fiber body.

15. A control method for the test apparatus according to any one of claims 1 to 14, comprising:

controlling the temperature of the adhesive and the surface temperature of the tested member, so as to control the temperature gradients of the bonding layer between the adhesive and the tested member; and

acquiring a plurality of groups of contact angles formed between the adhesive and the tested member at the different temperature gradients, wherein the temperature of the tested member and the temperature of the adhesive, corresponding to the smallest contact angle, serve as control parameters for forming a protective coating.

16. The control method according to claim 15, wherein the contact angles at the temperature gradients are acquired by acquiring the information of the meniscus formed between the tested member and the adhesive, and calculating the contact angles according to the information of the meniscus, wherein the information of the meniscus is an image or a video of the meniscus acquired via a camera apparatus.

Patentansprüche

1. Prüfvorrichtung zum Untersuchen der Benetzbarkeit eines Elements, mit:

einem Behälter (10), wobei innerhalb des Behälters (10) ein Klebstoffaufnahmehohlraum vorgesehen ist, der dafür konfiguriert ist, einen Klebstoff (100) aufzunehmen;

einem Positionierungselement, das dafür konfiguriert ist, ein geprüftes Element in dem Klebstoffaufnahmehohlraum des Behälters (10) zu positionieren, so dass ein Teil des geprüften Elements im Klebstoff platziert wird;

einem Klebstofferwärmungselement (12), das innerhalb oder außerhalb des Klebstoffaufnahmehohlraums angeordnet und dafür konfiguriert ist, den Klebstoff (100) zu erwärmen;

einem Klebstofftemperatursensor (11), der dafür konfiguriert ist, eine Temperatur des Klebstoffs innerhalb des Klebstoffaufnahmehohlraums zu messen;

einem Erfassungselement, das dafür konfiguriert ist, Information über einen Meniskus zu erfassen, der zwischen dem geprüften Element und dem Klebstoff (100) gebildet wird; und

einer Steuereinheit (22), die dafür konfiguriert ist, den Betrieb des Klebstofferwärmungselements (12) zu steuern, um zu veranlassen, dass der Klebstoff (100) unterschiedliche Temperaturen aufweist, gemäß der erfassten Information über den Meniskus bei den unterschiedlichen Temperaturen entsprechende Kontaktwinkel zwischen dem geprüften Element und dem Klebstoff (100) zu berechnen, und eine Temperatur des Klebstoffs (100) zu erfassen, die einem kleinsten Kontaktwinkel entspricht;

dadurch gekennzeichnet, dass

die Vorrichtung ferner eine Elementheizeinrichtung und einen Elementtemperatursensor (16) aufweist, wobei:

die Elementheizeinrichtung im Inneren des geprüften Bauteils angeordnet und dafür konfiguriert ist, eine bedeckte Oberfläche des geprüften Elements zu erwärmen;

der Elementtemperatursensor (16) dafür konfiguriert ist, eine Oberflächentemperatur des mit dem Klebstoff in Kontakt stehenden geprüften Elements zu messen; und

die Steuereinheit (22) ferner dafür konfiguriert ist, einen Betrieb der Elementheizeinrichtung zu steuern, um zu veranlassen, dass das geprüfte Element unterschiedliche Temperaturen aufweist, die Information über den Meniskus für unterschiedliche Temperaturgradienten einer Verbindungsschicht zwischen dem geprüften Element und dem Klebstoff zu erfassen, entsprechende Kontaktwinkel gemäß der Information über den Meniskus zu berechnen, und eine Temperatur des geprüften Elements und die Temperatur des Klebstoffs zu erfassen, die dem kleinsten Kontaktwinkel entsprechen.

2. Prüfvorrichtung nach Anspruch 1, wobei

   die Elementheizeinrichtung im Voraus im Inneren des geprüften Elements eingebettet wird,
   der Elementtemperatursensor (16) einen Temperaturerfassungsteil und einen leitenden Teil aufweist,
   der Temperaturerfassungsteil dafür konfiguriert ist, eine Temperatur zu messen, und mindestens ein Teil des Temperaturerfassungsteils an der bedeckten Oberfläche des geprüften Elements anliegt, und
   der leitende Teil im Inneren des geprüften Elements eingebettet ist, wobei ein Ende des leitenden Teils mit dem Temperaturerfassungsteil verbunden ist und ein anderes Ende des leitenden Teils sich aus dem Inneren des geprüften Elements heraus erstreckt, um mit der Steuereinheit (22) verbunden zu werden.

3. Prüfvorrichtung nach Anspruch 2, ferner mit einem Innentemperatursensor, der im Inneren des geprüften Elements angeordnet und dafür konfiguriert ist, eine Innentemperatur des geprüften Elements zu erfassen.

4. Prüfvorrichtung nach einem der Ansprüche 1 bis 3, wobei das Positionierungselement aufweist:

   einen Hebel (19), der in der Lage ist, sich um einen festen Drehpunkt zu drehen, wobei das geprüfte Element, das sich innerhalb des Klebstoffaufnahmehohlraums befindet, an einem Ende des Hebels (19) aufgehängt ist, ein Gewichtsausgleichselement (17) an einem anderen Ende des Hebels (19) angeordnet ist, und das Gewichtsausgleichselement (17) dafür konfiguriert ist, eine auf das geprüfte Element ausgeübte Kraft auszugleichen, so dass sich der Hebel (19) in einer ausgeglichenen Position befindet,
   wobei die Prüfvorrichtung ferner eine auf dem Boden oder auf einem Prüfstand getragene Halterung (18) aufweist, wobei der feste Drehpunkt des Hebels (19) an einer Oberseite der Halterung (18) ausgebildet ist.

5. Prüfvorrichtung nach Anspruch 4, wobei der Behälter (10) eine Bodenwand (101), eine Umfangswand (102) und eine obere Wand (103) aufweist, wobei die Bodenwand (101), die Umfangswand (102) und die obere Wand (103) einen Aufnahmehohlraum umschließen und der Klebstoffaufnahmehohlraum Teil des Aufnahmehohlraums ist, und wobei die Prüfvorrichtung ferner eine Zugschnur oder einen Zugstab aufweist, wobei ein unteres Ende der Zugschnur oder des Zugstabs mit einem oberen Abschnitt des geprüften Elements verbunden ist und ein oberes Ende der Zugschnur oder des Zugstabs sich durch ein Durchgangsloch in der oberen Wand erstreckt und mit einem entsprechenden Ende des Hebels (19) verbunden ist, und
   wobei der Aufnahmehohlraum des Behälters (10) ferner einen Gashohlraum aufweist, der Gashohlraum um den Klebstoffaufnahmehohlraum herum oder oberhalb des Klebstoffaufnahmehohlraums angeordnet ist und der Gashohlraum dafür konfiguriert ist, mit einem Gas gefüllt zu werden, das eine Testbedingung erfüllt.

6. Prüfvorrichtung nach Anspruch 1, ferner mit einem Antriebselement, wobei das Antriebselement dafür konfiguriert ist, den Behälter (10) derart anzutreiben, dass er sich um eine vertikale Mittelachse davon dreht, wobei:

   das Klebstofferwärmungselement (12) ein Heiznetz (121) ist, das gleichmäßig innerhalb des Klebstoffaufnahmehohlraums verteilt ist, und/oder
   das Klebstofferwärmungselement (12) innerhalb einer Innenwand des Behälters (10) angeordnet ist und ein Verdrahtungsende des Klebstofferwärmungselements (12) zu einer Außenseite des Behälters (10) freiliegt.

7. Prüfvorrichtung nach einem der Ansprüche 1 bis 3 und 6, wobei die durch das Erfassungselement erfasste Information über den Meniskus ein Bild oder ein Video des Meniskus ist, ein Signalausgangsanschluss des Erfassungselements mit einem Signaleingangsende der Steuereinheit (22) verbunden ist und das Bild oder das Video des Meniskus an die Steuereinheit (22) überträgt, und die Steuereinheit (22) eine Bildverarbeitung oder Videoverarbeitung des Bildes oder des Videos des Meniskus ausführt, um die Kontaktwinkel zwischen dem Klebstoff und dem geprüften Element zu erfassen.

8. Prüfvorrichtung nach Anspruch 7, wobei das Erfassungselement eine Kamera (33), ein Mikroskop (31) und eine Bildsammelkarte (32) aufweist,

   wobei die Kamera (33) dafür konfiguriert ist, das Bild des Meniskus zu erfassen,
   das Mikroskop (31) dafür konfiguriert ist, das durch die Kamera (33) erfasste Bild des Meniskus zu vergrößern, und
   die Bildsammelkarte (32) das durch das Mikroskop (31) vergrößerte Bild des Meniskus empfängt und das Bild des Meniskus mit einer durch die Steuereinheit (22) bestimmten Abtastrate auf einem Anzeigebildschirm anzeigt.

9. Prüfvorrichtung nach Anspruch 4, wobei die Elementheizeinrichtung ein Heizdraht (15) ist, das geprüfte Element ein faserverstärktes Material (13) ist, das durch den Heizdraht (15) und eine Mehrzahl von Fasern gewebt ist, und der Heizdraht (15) innerhalb der Fasern eingewickelt ist, und die Prüfvorrichtung ferner einen Aufhängerahmen (14) aufweist, wobei das faserverstärkte Material (13) flach auf dem Aufhängerahmen (14) angeordnet ist und ein oberes Ende des Aufhängerahmens (14) mit dem Hebel (19) verbunden ist.

10. Prüfvorrichtung nach Anspruch 7, wobei

der Behälter (10) eine äußere Schale (104) und eine innere Schale (105) aufweist, der Klebstoffaufnahmehohlraum innerhalb der inneren Schale (105) ausgebildet ist, ein wärmeisolierender Hohlraum zwischen der inneren Schale (104) und der äußeren Schale (105) ausgebildet ist und ein wärmeisolierendes Material im wärmeisolierenden Hohlraum enthalten ist, oder
die äußere Schale (104) einen Einlass (104a) und einen Auslass (104b) aufweist, die mit dem wärmeisolierenden Hohlraum kommunizieren, und der Einlass (104a) und der Auslass (104b) mit einem externen wärmeisolierenden Mediumkreislauf verbunden sind.

11. Prüfvorrichtung nach einem der Ansprüche 1 bis 3 und 6, wobei der Klebstofftemperatursensor (11) an einer Grenze einer durch den Klebstoff und das geprüfte Element gebildeten Verbindungsschicht angeordnet ist.

12. Prüfvorrichtung nach Anspruch 1, wobei das geprüfte Element ein Magnetpolelement (40) oder ein faserverstärktes Material ist,
wobei das Magnetpolelement (40) aufweist:

einen Magnetkörper (41),
wobei die Elementheizeinrichtung innerhalb des Magnetkörpers (41) angeordnet und dafür konfiguriert ist, den Magnetkörper (41) zu erwärmen, und
der Elementtemperatursensor dafür konfiguriert ist, eine Oberflächentemperatur des Magnetkörpers (41) zu messen, und
wobei das faserverstärkte Material aufweist:

einen Faserkörper,
wobei die Elementheizeinrichtung innerhalb des Faserkörpers angeordnet und dafür konfiguriert ist, den Faserkörper zu erwärmen, und
der Elementtemperatursensor dafür konfiguriert ist, eine Oberflächentemperatur des Faserkörpers zu messen.

13. Prüfvorrichtung nach Anspruch 12, wobei die Elementheizeinrichtung innerhalb des Magnetkörpers (41) gleichmäßig ausgebildet und in der Nähe einer Oberfläche des Magnetkörpers (41) angeordnet ist,

wobei eine Außenfläche der Elementheizeinrichtung von einem Isoliermaterial umhüllt ist,
wobei die Elementheizeinrichtung ein Heizdraht, ein Heizstab oder ein Flüssigkeitsheizrohr ist, oder wobei die Elementheizeinrichtung ein kontinuierliches elektrisches Heizelement innerhalb des Magnetkörpers (41) bildet, oder wobei die Elementheizeinrichtung eine Netzstruktur ist, die innerhalb des Magnetkörpers (41) durch ein elektrisches Heizelement ausgebildet ist,
wobei der Elementtemperatursensor einen Temperaturerfassungsteil und einen leitenden Teil aufweist, wobei der Temperaturerfassungsteil dafür konfiguriert ist, eine Temperatur zu messen, und wobei mindestens ein Teil des Temperaturerfassungsteils an einer Außenfläche des Magnetkörpers (41) anliegt und der leitende Teil im Inneren des Magnetkörpers (41) eingebettet ist, wobei ein Ende des leitenden Teils mit dem Temperaturerfassungsteil verbunden ist und ein anderes Ende des leitenden Teils an einer Außenseite des Magnetkörpers (41) freiliegt, und
wobei die Testvorrichtung ferner einen Innentemperatursensor aufweist, der im Inneren des Magnetkörpers (41) angeordnet und dafür konfiguriert ist, eine Innentemperatur des Magnetkörpers (41) zu erfassen.

14. Prüfvorrichtung nach Anspruch 12, wobei die Elementheizeinrichtung im Inneren des faserverstärkten Materials gleichmäßig eingewickelt und in der Nähe einer Oberfläche des faserverstärkten Materials angeordnet ist,

wobei die Elementheizeinrichtung ein Heizdraht (15) ist, der Faserkörper eine Mehrzahl von Fasern aufweist, der Heizdraht (15) und die Fasern miteinander verwoben sind, um das faserverstärkte Material zu bilden, und

der Heizdraht (15) von den Fasern umwickelt ist, und
wobei der Elementtemperatursensor einen Temperaturerfassungsteil und einen leitenden Teil aufweist, wobei der Temperaturerfassungsteil dafür konfiguriert ist, eine Temperatur zu messen, und wobei mindestens ein Teil des Temperaturerfassungsteils an einer Außenfläche des faserverstärkten Materials anliegt, der leitende Teil im Inneren des Faserkörpers eingebettet ist, ein Ende des leitenden Teils mit dem Temperaturerfassungsteil verbunden ist und ein anderes Ende des leitenden Teils an einer Außenseite des Faserkörpers freiliegt, und
wobei die Prüfvorrichtung ferner einen Innentemperatursensor aufweist, der im Inneren des Faserkörpers angeordnet und dafür konfiguriert ist, eine Innentemperatur des Faserkörpers zu erfassen.

15. Steuerverfahren für die Prüfvorrichtung nach einem der Ansprüche 1 bis 14, mit den Schritten:

Steuern der Temperatur des Klebstoffs und der Oberflächentemperatur des geprüften Elements zum Steuern der Temperaturgradienten der Verbindungsschicht zwischen dem Klebstoff und dem geprüften Element; und
Erfassen mehrerer Gruppen von Kontaktwinkeln, die zwischen dem Klebstoff und dem geprüften Element bei den verschiedenen Temperaturgradienten gebildet werden, wobei die Temperatur des geprüften Elements und die Temperatur des Klebstoffs, die dem kleinsten Kontaktwinkel entsprechen, als Steuerparameter zum Ausbilden einer Schutzbeschichtung dienen.

16. Steuerverfahren nach Anspruch 15, wobei die Kontaktwinkel bei den Temperaturgradienten durch Erfassen der Information über den zwischen dem geprüften Element und dem Klebstoff gebildeten Meniskus und Berechnen der Kontaktwinkel gemäß der Information über den Meniskus erfasst werden, wobei die Information über den Meniskus ein Bild oder ein Video des Meniskus ist, das über eine Kamera erfasst wird.

Revendications

1. Appareil de test pour une recherche de mouillabilité d'élément, comprenant :

un récipient (10), dans lequel une cavité de placement d'adhésif conçue pour maintenir un adhésif (100) est agencée à l'intérieur du récipient (10) ;
un élément de positionnement, conçu pour positionner un élément testé au niveau de la cavité de placement d'adhésif du récipient (10), de telle sorte qu'une partie de l'élément testé est placée dans l'adhésif ;
un élément de chauffage d'adhésif (12), disposé à l'intérieur ou à l'extérieur de la cavité de placement d'adhésif et conçu pour chauffer l'adhésif (100) ;
un capteur de température d'adhésif (11), conçu pour mesurer une température de l'adhésif à l'intérieur de la cavité de placement d'adhésif ;
un élément de collecte, conçu pour acquérir des informations d'un ménisque formé entre l'élément testé et l'adhésif (100) ; et
un dispositif de commande (22), conçu pour commander une opération de l'élément de chauffage d'adhésif (12) pour faire que l'adhésif (100) soit à différentes températures, calculer, en fonction des informations acquises du ménisque aux différentes températures, des angles de contact correspondants entre l'élément testé et l'adhésif (100), et acquérir une température de l'adhésif (100) correspondant à un angle de contact le plus faible, **caractérisé en ce qu'**il comprend en outre un dispositif de chauffage d'élément et un capteur de température d'élément (16), où :

le dispositif de chauffage d'élément est disposé à l'intérieur de l'élément testé et conçu pour chauffer une surface recouverte de l'élément testé ;
le capteur de température d'élément (16) est conçu pour mesurer une température de surface de l'élément testé en contact avec l'adhésif ; et
le dispositif de commande (22) est en outre conçu pour commander l'opération du dispositif de chauffage d'élément pour faire que l'élément testé soit à différentes températures, acquiert les informations du ménisque pour différents gradients de température d'une couche de liaison entre l'élément testé et l'adhésif, calcule des angles de contact correspondants en fonction des informations du ménisque, et acquiert une température de l'élément testé et la température de l'adhésif correspondant à l'angle de contact le plus faible.

2. Appareil de test selon la revendication 1, dans lequel le dispositif de chauffage d'élément est enfoui à l'avance à l'intérieur de l'élément testé ; le capteur de température d'élément (16) comprend une partie détectant la température et une partie conductrice ; la partie détectant la température est conçue pour mesurer une température, et au moins une partie de la partie détectant la température vient en butée contre la surface recouverte de l'élément testé ; et la partie conductrice est enfouie à l'intérieur de l'élément testé, une extrémité de la partie conductrice est reliée à la partie détectant la température, et l'autre partie de la partie conductrice s'étend hors de l'intérieur de l'élément testé pour qu'elle soit reliée au dispositif de commande (22).

3. Appareil de test selon la revendication 2, comprenant en outre un capteur de température interne, qui est disposé à l'intérieur de l'élément testé et conçu pour détecter une température interne de l'élément testé.

4. Appareil de test selon l'une quelconque des revendications 1 à 3, dans lequel l'élément de positionnement comprend :

un levier (19) capable de tourner autour d'un pivot fixe, l'élément testé situé à l'intérieur de la cavité de placement d'adhésif étant suspendu au niveau d'une extrémité du levier (19), un élément d'équilibrage de poids (17) étant disposé au niveau de l'autre extrémité du levier (19), et l'élément d'équilibrage de poids (17) étant conçu pour équilibrer une force sur l'élément testé de sorte que le levier (19) soit au niveau d'une position équilibrée,
l'appareil de test comprenant en outre une console (18) supportée sur le sol ou un banc d'essai, le pivot fixe du levier (19) étant formé au niveau d'une partie supérieure de la console (18).

5. Appareil de test selon la revendication 4, dans lequel le récipient (10) comprend une paroi inférieure (101), une paroi périphérique (102) et une paroi supérieure (103), la paroi inférieure (101), la paroi périphérique (102) et la paroi supérieure (103) enserrent une cavité contenante et la cavité de placement d'adhésif fait partie de la cavité contenante ; et l'appareil de test comprend en outre un cordon de tirage ou une tige de tirage, une extrémité inférieure du cordon de tirage ou de la tige de tirage est reliée à une partie supérieure de l'élément testé, et une extrémité supérieure du cordon de tirage ou de la tige de tirage passe à travers un trou de passage au niveau de la paroi supérieure et est reliée à une extrémité correspondante du levier (19), et
dans lequel la cavité contenante du récipient (10) comprend en outre une cavité de gaz, la cavité de gaz est située autour de la cavité de placement d'adhésif ou au-dessus de la cavité de placement d'adhésif, et la cavité de gaz est conçue pour être remplie avec un gaz qui répond à une condition de test.

6. Appareil de test selon la revendication 1, comprenant en outre un élément de puissance, l'élément de puissance étant conçu pour entraîner le récipient (10) à tourner autour d'un axe central vertical de celui-ci, dans lequel :

l'élément de chauffage d'adhésif (12) est un filet chauffant (121) distribué uniformément à l'intérieur de la cavité de placement d'adhésif ; et/ou
l'élément de chauffage d'adhésif (12) est disposé à l'intérieur d'une paroi interne du récipient (10), et une extrémité de câblage de l'élément de chauffage d'adhésif (12) est exposée vers un extérieur du récipient (10).

7. Appareil de test selon l'une quelconque des revendications 1 à 3 et 6, dans lequel les informations du ménisque acquises par l'élément de collecte est une image ou une vidéo du ménisque, un port de sortie de signal de l'élément de collecte est relié à une extrémité d'entrée de signal du dispositif de commande (22) et transmet l'image ou la vidéo du ménisque au dispositif de commande (22), et le dispositif de commande (22) réalise un traitement d'image ou un traitement de vidéo sur l'image ou la vidéo du ménisque afin d'acquérir les angles de contact entre l'adhésif et l'élément testé.

8. Appareil de test selon la revendication 7, dans lequel l'élément de collecte comprend un appareil de caméra (33), un microscope (31) et une carte de collecte d'image (32) ;
l'appareil de caméra (33) est conçu pour acquérir l'image du ménisque ; le microscope (31) est conçu pour agrandir l'image du ménisque qui est acquise par l'appareil de caméra (33) ; et la carte de collecte d'image (32) reçoit l'image du ménisque qui est agrandie par le microscope (31), et affiche sur un écran d'affichage l'image du ménisque avec un taux d'échantillonnage déterminé par le dispositif de commande (22).

9. Appareil de test selon la revendication 4, dans lequel le dispositif de chauffage d'élément est un fil chauffant (15), l'élément testé est un matériau renforcé de fibres (13), qui est tissé par le fil chauffant (15) et une pluralité de fibres, et le fil chauffant (15) est enveloppé à l'intérieur des fibres ; et l'appareil de test comprend en outre un cadre de suspension (14), le matériau renforcé de fibres (13) est positionné à plat sur le cadre de suspension (14), et une extrémité supérieure du cadre de suspension (14) est reliée au levier (19).

10. Appareil de test selon la revendication 7, dans lequel le récipient (10) comprend une coque externe (104) et une coque interne (105), la cavité de placement d'adhésif est formée à l'intérieur de la coque interne (105), une cavité

d'isolation thermique est formée entre la coque interne (104) et la coque externe (105), et un matériau d'isolation thermique est contenu dans la cavité d'isolation thermique ; ou
la coque externe (104) est munie d'une entrée (104a) et d'une sortie (104b), qui sont en communication avec la cavité d'isolation thermique, et l'entrée (104a) et la sortie (104b) sont reliées à un circuit de milieu d'isolation thermique externe.

11. Appareil de test selon l'une quelconque des revendications 1 à 3 et 6, dans lequel le capteur de température d'adhésif (11) est disposé au niveau d'une limite d'une couche de liaison formée par l'adhésif et l'élément testé.

12. Appareil de test selon la revendication 1, dans lequel l'élément testé est un élément de pôle magnétique (40) ou un matériau renforcé de fibres,
dans lequel l'élément de pôle magnétique (40) comprend :

un corps magnétique (41) ;
dans lequel le dispositif de chauffage d'élément est disposé à l'intérieur du corps magnétique (41) et conçu pour chauffer le corps magnétique (41) ; et
le capteur de température d'élément est conçu pour mesurer une température de surface du corps magnétique (41), et
dans lequel le matériau renforcé de fibres comprend :

un corps de fibres ;
dans lequel le dispositif de chauffage d'élément est disposé à l'intérieur du corps de fibres et conçu pour chauffer le corps de fibres ; et
le capteur de température d'élément est conçu pour mesurer une température de surface du corps de fibres.

13. Appareil de test selon la revendication 12, dans lequel le dispositif de chauffage d'élément est formé uniformément à l'intérieur du corps magnétique (41), et est disposé près d'une surface du corps magnétique (41),

dans lequel une surface externe du dispositif de chauffage d'élément est enveloppée par un matériau d'isolation,
dans lequel le dispositif de chauffage d'élément est un fil chauffant, une tige chauffante, ou un tuyau chauffant un liquide, ou le dispositif de chauffage d'élément forme un élément de chauffage électrique continu à l'intérieur du corps magnétique (41), ou le dispositif de chauffage d'élément est une structure en filet formée à l'intérieur du corps magnétique (41) par un élément de chauffage électrique,
dans lequel le capteur de température d'élément comprend une partie détectant la température et une partie conductrice ; la partie détectant la température est conçue pour mesurer une température, et au moins une partie de la partie détectant la température vient en butée contre une surface externe du corps magnétique (41) ; et la partie conductrice est enfouie à l'intérieur du corps magnétique (41), une extrémité de la partie conductrice est reliée à la partie détectant la température, et l'autre partie de la partie conductrice est exposée à un extérieur du corps magnétique (41), et
dans lequel l'appareil de test comprend en outre un capteur de température interne, disposé à l'intérieur du corps magnétique (41) et conçu pour détecter une température interne du corps magnétique (41).

14. Appareil de test selon la revendication 12, dans lequel le dispositif de chauffage d'élément est enveloppé uniformément à l'intérieur du matériau renforcé de fibres, et est disposé près d'une surface du matériau renforcé de fibres,

dans lequel le dispositif de chauffage d'élément est un fil chauffant (15), le corps de fibres comprend une pluralité de fibres, le fil chauffant (15) et les fibres sont tissés ensemble pour former le matériau renforcé de fibres, et le fil chauffant (15) est enveloppé par les fibres, et
dans lequel le capteur de température d'élément comprend une partie détectant la température et une partie conductrice ; la partie détectant la température est conçue pour mesurer une température, et au moins une partie de la partie détectant la température vient en butée contre une surface externe du matériau renforcé de fibres ; la partie conductrice est enfouie à l'intérieur du corps de fibres, une extrémité de la partie conductrice est reliée à la partie détectant la température, et l'autre partie de la partie conductrice est exposée à un extérieur du corps de fibres, et
dans lequel l'appareil de test comprend en outre un capteur de température interne, disposé à l'intérieur du corps de fibres et conçu pour détecter une température interne du corps de fibres.

15. Procédé de commande pour l'appareil de test selon l'une quelconque des revendications 1 à 14, comprenant :

la commande de la température de l'adhésif et de la température de surface de l'élément testé de manière à commander les gradients de température de la couche de liaison entre l'adhésif et l'élément testé ; et l'acquisition d'une pluralité de groupes d'angles de contact formés entre l'adhésif et l'élément testé aux différents gradients de température, la température de l'élément testé et la température de l'adhésif, correspondant à l'angle de contact le plus faible, servant de paramètres de commande pour la formation d'un revêtement protecteur.

16. Procédé de commande selon la revendication 15, dans lequel les angles de contact aux gradients de température sont acquis par l'acquisition d'informations du ménisque formé entre l'élément testé et l'adhésif, et le calcul des angles de contact en fonction des informations du ménisque, les informations du ménisque étant une image ou une vidéo du ménisque acquise par le biais d'un appareil de caméra.

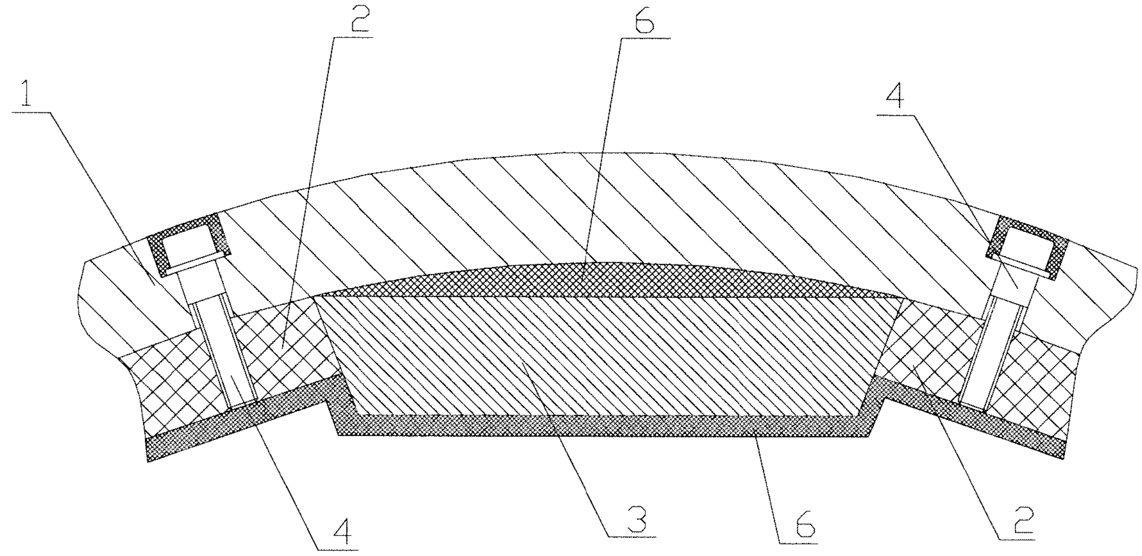

Figure 1

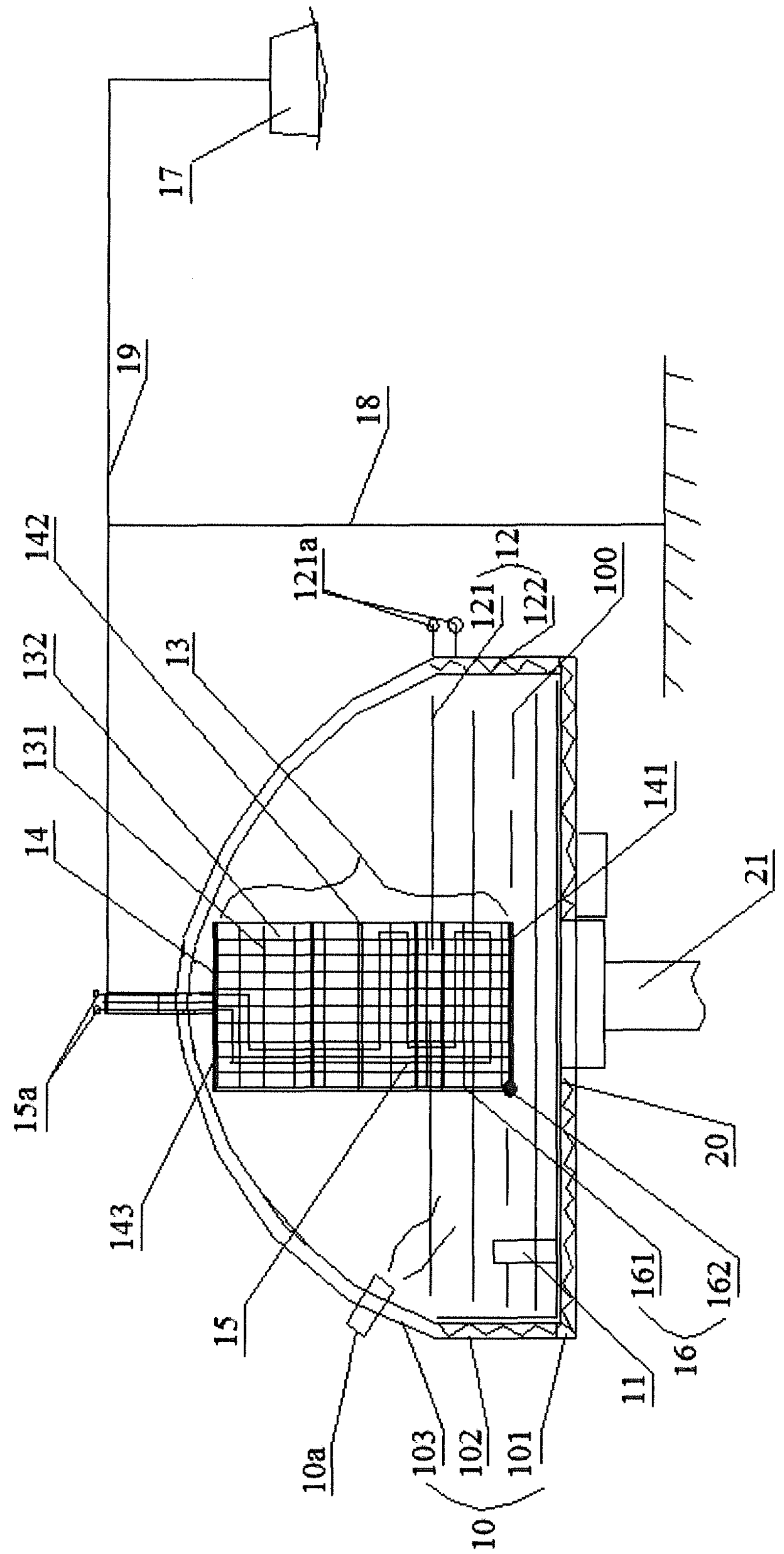
17
19
18
142
121a
12
121
122
100
13
132
131
14
141
21
15a
143
15
20
161
162
16
11
10a
103
102
101
10

Figure 2

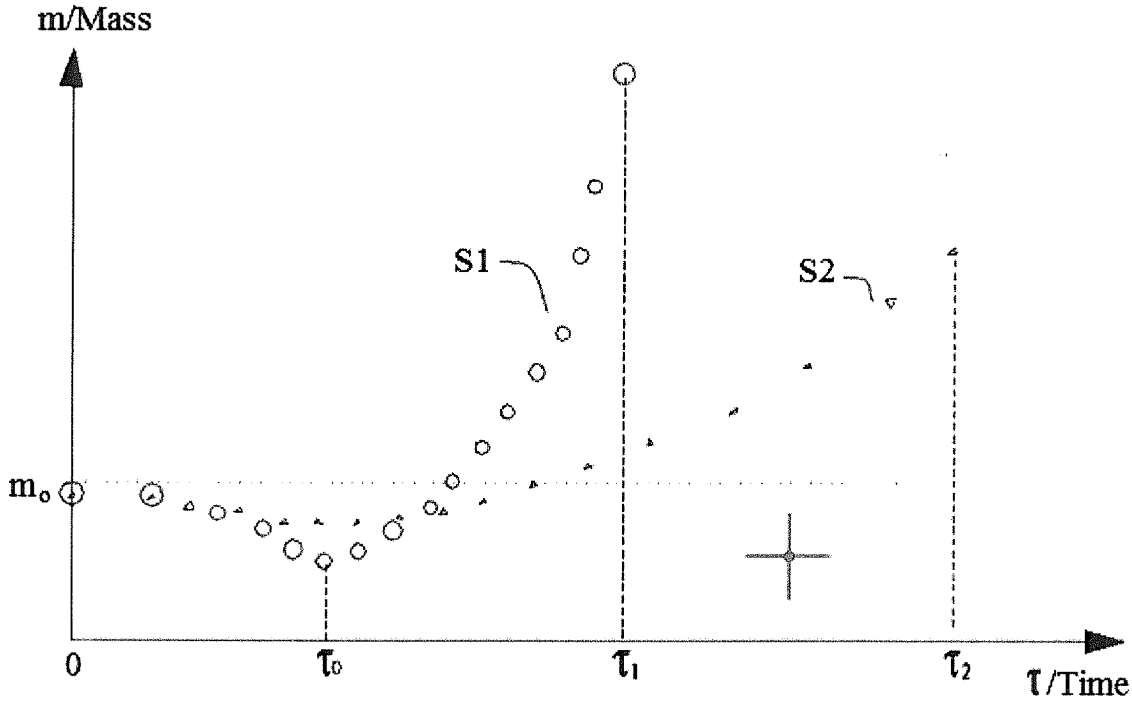

Figure 3

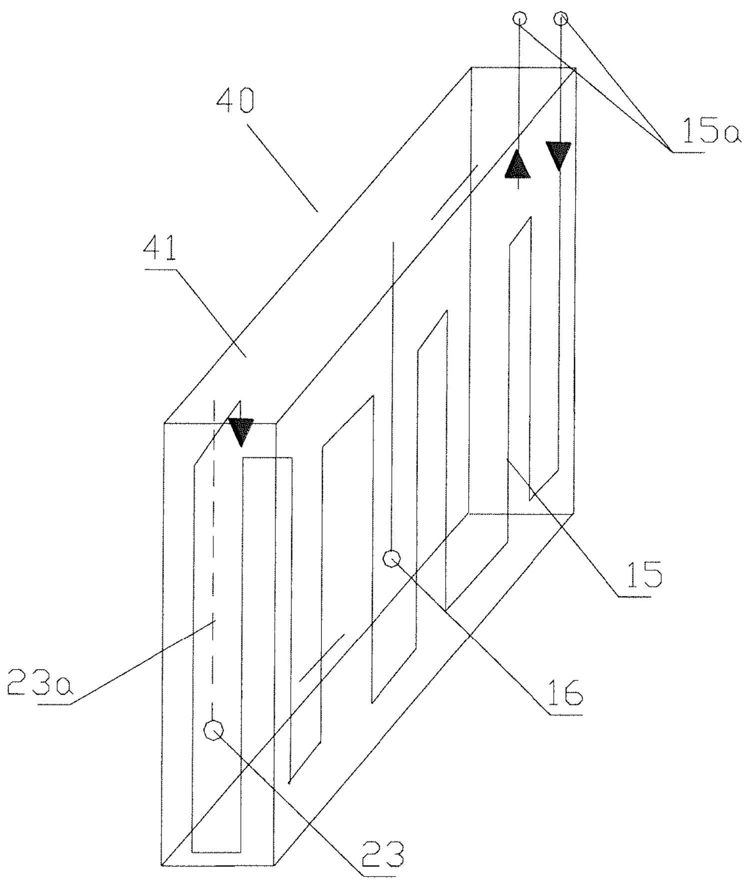

Figure 4

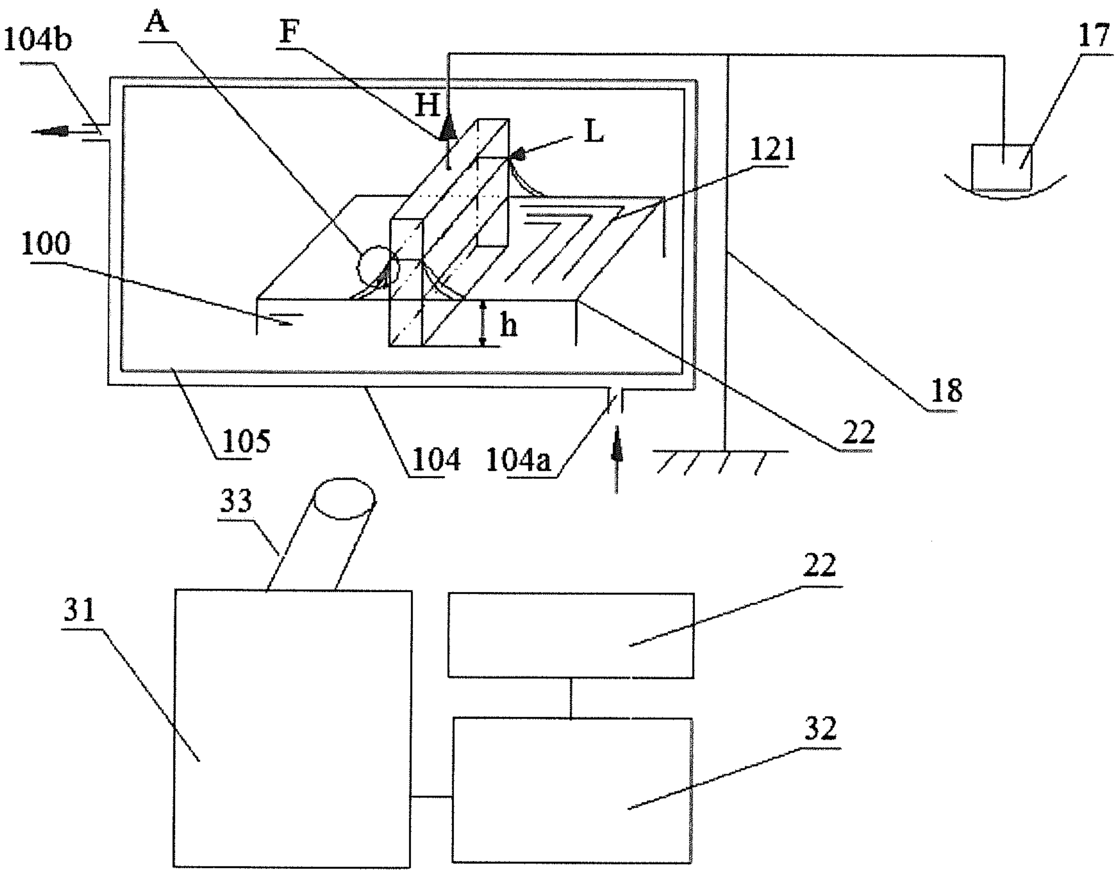

Figure 5

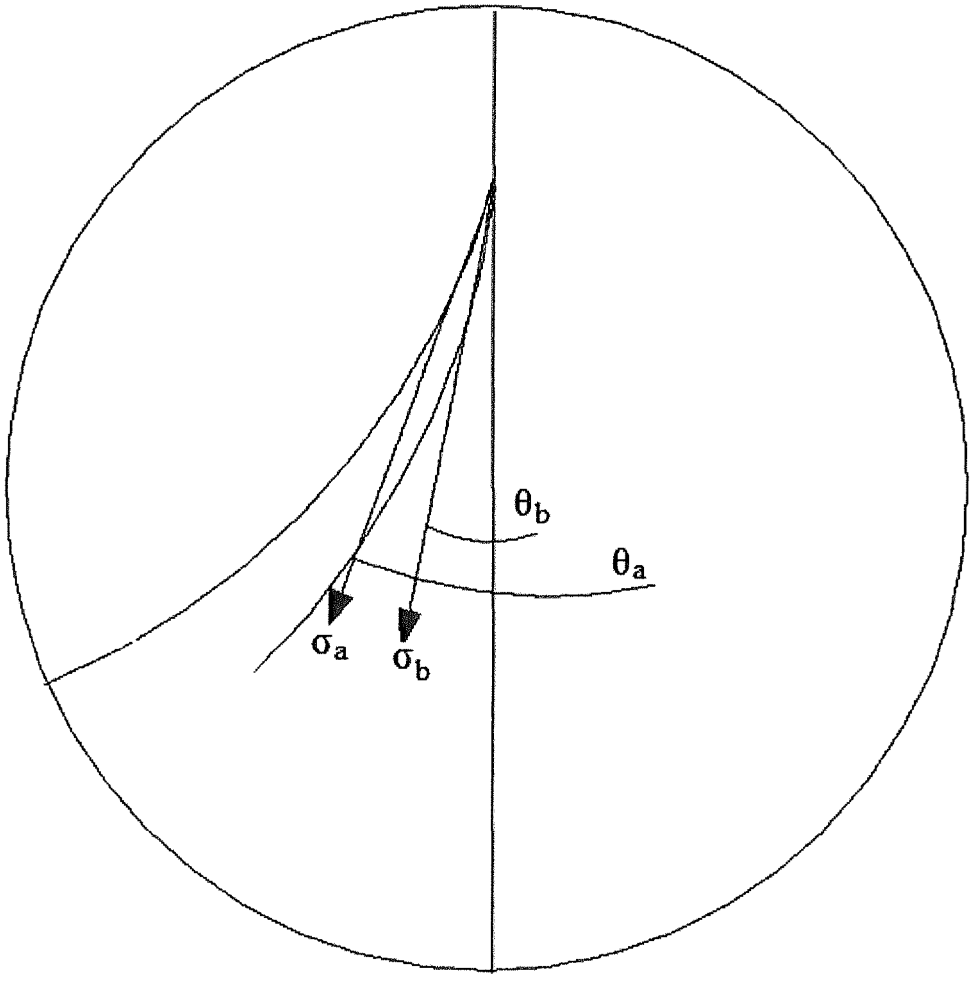

Figure 6

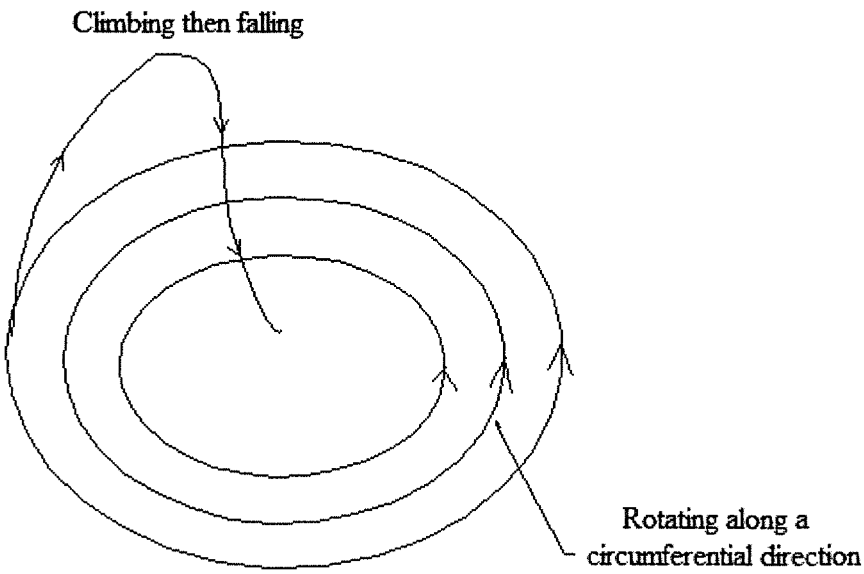
Climbing then falling
Rotating along a circumferential direction

Figure 7

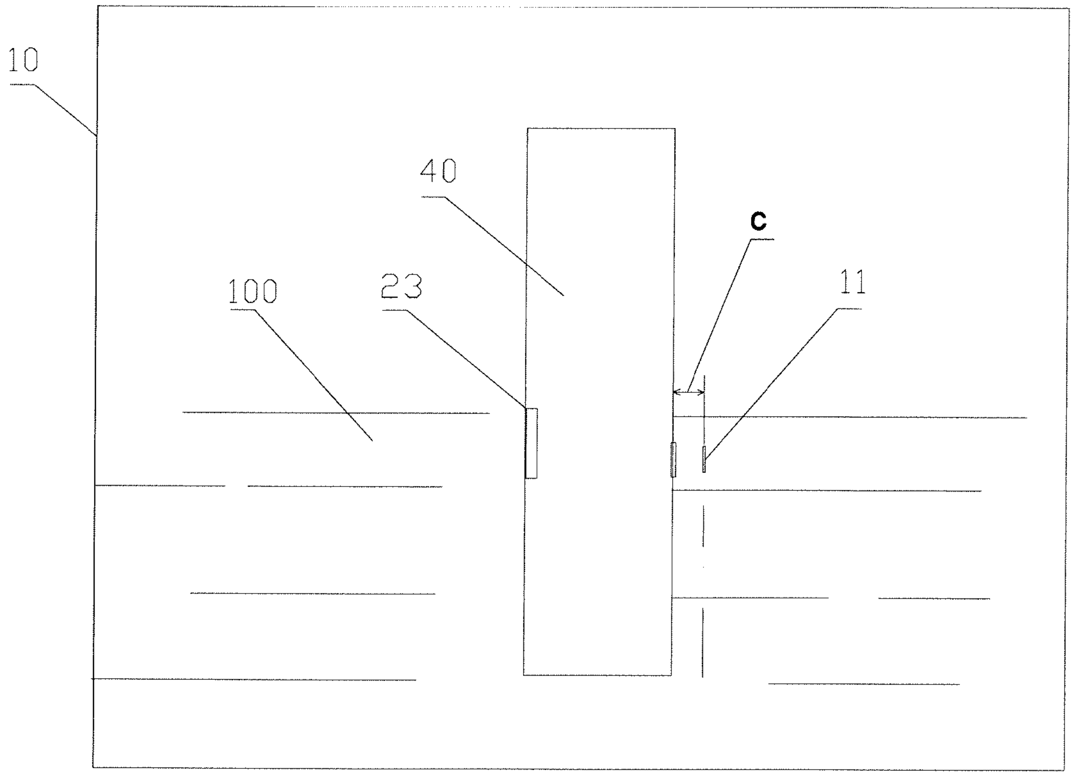

Figure 8

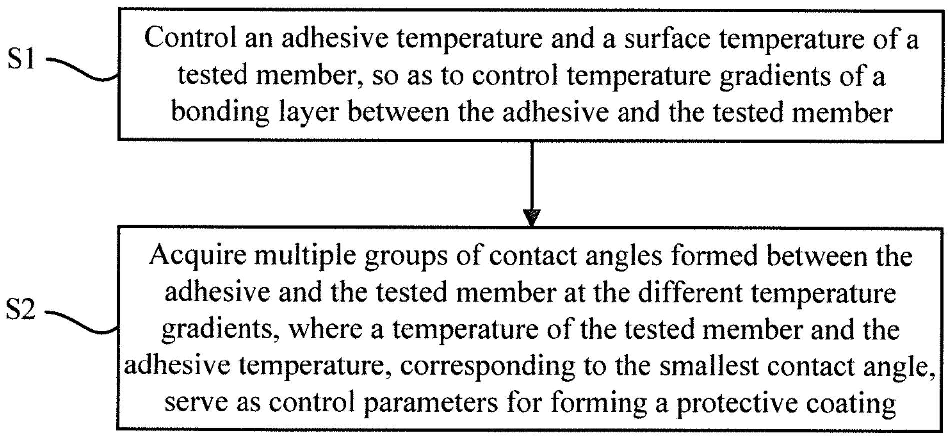

Figure 9

REFERENCES CITED IN THE DESCRIPTION

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